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A decision aid model for a maneuver force commander that incorporates the quantified judgment model

Moughon, James Coleman

Monterey, California. Naval Postgraduate School

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THESIS

A DECISION AID MODEL FOR A MANEUVER FORCE COMMANDER THAT INCORPORATES THE QUANTIFIED JUDGMENT MODEL

by

James Coleman Moughon, III

March 1989

Thesis Co-Advisors: Bark K. Mansager
Thomas M. Mitchell

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The Quantified Judgment Model (QJM) served as the algorithm in this decision aid model. The QJM is a combat model that analyzes ground combat with a primary focus on the historical aspect of combat. Factors that served as input for the decision aid model included: 1. Initial force structure for a U.S. and Soviet force, 2. non tactical variables that influence the battle, 3. intelligence, 4. operational and environmental factors, and 5. current doctrine. (Continued)

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A Decision Aid Model for a Maneuver Force Commander that Incorporates the Quantified Judgment Model

by

James Coleman Moughon, III
Captain, U.S. Army
B.S., University of Georgia, 1979

Submitted in partial fulfillment of the requirements for the degree of

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March 1989

ABSTRACT

The commander on the modern battlefield has the responsibility of supervising more assets and evaluating more information than ever before. Therefore, there exists a need for an aid to assist the commander in selecting a recommended course of action. The purpose of this thesis was to develop a tactical decision aid model that would assist the commander in selecting a course of action.

The Quantified Judgment Model (QJM) served as the algorithm in this decision aid model. The QJM is a combat model that analyzes ground combat with a primary focus on the historical aspect of combat. Factors that served as input for the decision aid model included:

1. initial force structure for a US and Soviet force,
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THESIS DISCLAIMER

The reader is cautioned that computer programs developed in this research may not have been exercised for all cases of interest. While every effort has been made, within the time available, to ensure that the programs are free of computational and logic errors, they cannot be considered validated. Any application of these programs without additional verification is at the risk of the user.

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TO GOD BE THE GLORY

I. INTRODUCTION

A. BACKGROUND

One of the major problems with the majority of the land combat models currently used is that they are constructed using game theory and estimates of weapon systems' capabilities. Colonel T. N. Dupuy, U.S. Army (retired), realized this problem and developed the Quantified Judgment Model (QJM) which analyses ground combat focussing primarily on historical lessons learned. Dupuy stated that if enough reliable data could be collected from military history, it should provide basic insights into the nature of the conflict and indicate possible trends in planning for the future. [Ref 1, page xxi]

Many distinguished military leaders both past and present share the same views as Dupuy on the value of military history. Admiral Hyman Rickover wrote: "A page of history is worth a book of logic." Dupuy states that since military science is unable to test its theories in a laboratory, the laboratory for the soldier is military history. [Ref 1, page xxii]

B. COMMON MISCONCEPTIONS

The combat power of a force considers the strength of the force, any operational and environmental factors that may have an impact on the force, and the quality of the troops. Many tacticians believe that in order for the attacker to be successful in battle, the attacker must possess a three-to-one combat power superiority over the defender. There are, however, countless examples throughout history that contradict this doctrine.

General Stonewall Jackson's Shenandoah Valley Campaign of 1862 is an example that does not conform to the three-to-one combat power superiority theory. Major General Nathaniel P. Banks of the Union Army remained in the Shenandoah Valley to prevent the Confederate Army from attacking Washington. The Union forces totaled about 18,000 men, while the Confederates under the command of Jackson numbered about 8,500 men. Jackson's major objectives were to keep the Shenandoah Valley from falling into the hands of the Union Army and to prevent Banks from providing logistical support to General McClellan and the Army of the Potomac.

In most of the battles during a two and a half month period, Jackson's forces were successful. Eventually, Banks received reinforcements that gave the Union Army an almost

four-to-one combat power superiority over the attacking Confederates. The major contributing factor to Jackson's success was that each time Banks received reinforcements Jackson would prevent the reinforcements from joining the parent unit. This made it extremely difficult for Banks to establish a unified command of his entire force. [Ref 4]

General Robert E. Lee's attack against the forces of Major General Joseph Hooker at Chancellorsville is another example which suggests that combat power is not the only factor which determines the outcome of a battle. The Confederate forces under the command of Lee had a force of about 61,000 men and 170 artillery pieces compared with a force of about 134,000 men and 404 artillery pieces in the Union Army. The key to the Confederate Army's success was the quality and experience of the leadership. [Ref 5] Other examples abound in history that contradict the three-to-one combat power ratio theory.

The critical component in all of these historical examples is that combat power, although important and paramount in the minds of the commander, is just one of many factors in the overall equation of successful combat. Dupuy and his associates developed a list of seventy-three such factors that affect combat. Some of these factors include: leadership, training, morale, experience, and technology. Since incorporating all seventy-three of these factors into any

decision aid would be extremely difficult, the decision aid developed in this thesis uses only the four factors found in the Unit Status Report (USR). This monthly report requires the commander to evaluate the unit in four major areas. These are: personnel, equipment readiness, equipment on hand, and training. Each commander is required to submit this evaluation to the next higher level of command.

C. PURPOSE

The primary purpose of this thesis is to develop a decision aid model that would provide the unit commander with a recommended course of action. This decision aid uses the QJM as the basis for the model. This algorithm analyzes various external factors that would have an impact on the battle and provides the commander with a recommended course of action. These external factors include:

1. initial force structure of the US and Soviet forces,
2. behavioral variables,
3. intelligence about the Soviet force,
4. operational and environmental factors, and
5. current doctrine.

The results from a ground combat simulation were a key factor in determining the force size for both the US and the Soviet forces in which the battle would end up in a draw; this is more commonly referred to as the combat breakpoint. This

breakpoint served as a baseline for varying the external factors in the model to determine critical levels of these factors that could have an important impact on the ultimate outcome of the battle as determined by the QJM. The components utilized in the decision aid model are factors that could not be incorporated in the computer simulation. The purpose of the decision aid was to incorporate these factors into the model. A more detailed discussion of the method in which these factors were incorporated into the model is included in Chapter 4.

II. THE JANUS COMPUTER MODEL AND THE QUANTIFIED JUDGMENT MODEL

A. INTRODUCTION

The purpose of the Janus simulation was to simulate ground combat between a US mechanized infantry force attacking a Soviet motorized rifle force in defensive positions. The simulation results were used to develop a combat breakpoint for this particular tactical scenario that served as input to the model used in the decision aid model.

The US and Soviet forces used in the simulation were strictly mechanized infantry forces. Fire support, close air support, engineer assets, and armor forces were not considered in the simulation, since these assets will vary depending on the tactical situation. By not varying the force, the model can make predictions about a mechanized infantry unit that is not task organized.

A force is considered task organized when the unit has forces attached to it that are not part of the same headquarters. For example, a mechanized infantry battalion is considered task organized when it has an armor company attached to it. The way in which units are task organized depends on the mission, type of enemy threat, the type of terrain, and the assets available to the force commander.

B. JANUS COMPUTER MODEL

Janus, developed in 1983 by the US Army Training and Doctrine Command Systems Analysis Activity, is used extensively throughout the US Army as its primary ground combat model. New versions of the model are being developed, and the model is considered by the Army modeling community to be one of the best ground combat simulation models available.

Janus is a player interactive, high resolution, stochastic ground combat simulation [Ref 6, page 6]. The model is interactive in that the player specifies the actions of the forces portrayed in the simulation. It is high resolution in that the model depicts detailed interactions of the individual combatants or weapon systems with none of the forces being aggregated into larger units. [Ref 6, page 6] It is stochastic in that the laws of probability determine whether engagements between two elements occur and the outcomes of those engagements.

The actions of the simulation are displayed on a high resolution monitor thus enabling the player to see the movement of the forces. The terrain resolution is an accurate portrayal of the terrain selected for the model making it easier for the player to deploy forces and select routes of movement.

At the end of each simulation, the player obtains a detailed printout of all actions that occurred during the simulation. These printouts enable the user to examine critical battle information, such as the time at which each combatant system is detected, the time at which each system fired, the time at which each system killed another system, and the time at which the system was killed.

In summary, the Janus model was selected for use in this thesis due to its wide acceptance throughout the Army, and its ability to display critical battle information. Additionally, the Janus model is highly flexible, thus making it easy for the user to tailor the model to accommodate any type of unit.

C. QUANTIFIED JUDGMENT MODEL

The QJM uses formulas developed from historical combat data to compare the relative combat power between two forces. The major factors in the QJM are those variables that affect the weapon systems' effectiveness and how well the weapon systems are employed. These formulas were developed from historical combat data compiled from over 200 battles that occurred between 1915 and 1973. The QJM also has the capability of incorporating what Dupuy calls "intangible variables" such as leadership, training, and morale. [Ref 1, page 280] The QJM is also unique in that it has the ability

to incorporate behavioral variables such as surprise and combat effectiveness [Ref 2 ,page 95].

The QJM examines and analyzes three major aspects of battles:

1. the extent to which each side is able to accomplish its assigned mission,

2. the ability of each side to gain or hold ground, and

3. the ability of a unit to accomplish its assigned mission while simultaneously being able to gain or hold key terrain. [Ref 2, page 42]

Dupuy claims that the QJM is one of the most accurate models available in predicting the outcomes of battles. For example, it compared sixty engagements that occurred in Italy between 1943 and 1944. In these sixty engagements, the QJM was able to predict the outcome of each battle with a high degree of accuracy. This same data served as input to a different theater level model that is used and widely accepted throughout the Army. This theater level model could not predict the outcomes of these same battles with any degree of accuracy. Dupuy and his associates have analyzed many other battles that consisted of different types of forces which were operating in different types of theaters. The results of these battles determined by the QJM were similar to results predicted by the QJM on the battles fought in Italy. [Ref 2, page 57] These tests indicate the validity and accuracy of the model.

1. Combat Power Equation

When analyzing the strength of an opposing force, the commander must consider a myriad of factors other than just the size of the force. In Dupuy's QJM, the combat power of the force has the capability of including all of these factors. The combat power of a force takes into account the strength of the force, any operational and environmental factors that may have an impact on the force, and the quality of the troops. Dupuy's combat power equation is;

$$P = S \times OE \times Q$$

where,

P	=	combat power of the force
S	=	force strength (number and type of vehicles and personnel)
OE	=	operational and environmental factors
Q	=	quality of the troops.

2. Force Strength Equation

The force strength equation takes into account a multitude of factors when determining the strength of a force. It analyzes the characteristics of each weapon system, the number of each type of weapon system, and any environmental factors that may have an impact on each weapon system [Ref 2, page 43]. Force strength is calculated as follows;

Force Strength (US): $S_{US} = \Sigma_{i=1,4} (n_i \times OLI_i \times V_i)$

Force Strength (Soviet): $S_{Soviet} = \Sigma_{i=5,6} (n_i \times OLI_i \times V_i)$

where,

S = Force Strength

n = the total number of each weapon system

OLI = Operational Lethality Index of each weapon system

V = environmental effects on the weapon system

i = weapon system index of summation

1 = Bradley Fighting Vehicle (US)

2 = Cavalry Fighting Vehicle (US)

3 = Improved Tow Vehicle (US)

4 = Dragon (US)

5 = BMP (Soviet)

6 = RPG-7 (Soviet).

D. FORCE STRUCTURE

The initial force structure of the simulation consisted of a US mechanized infantry battalion attacking a Soviet motorized rifle company in prepared defensive positions. The US mechanized infantry battalion was organized into four companies. The battalion contained a total of fifty-five Bradley Fighting Vehicles (BFVs), six Cavalry Fighting Vehicles (CFVs), twelve Improved Tow Vehicles (ITVs), and thirty-six medium antitank weapons (Dragons) that were mounted on the BFVs.

The initial Soviet force consisted of one motorized rifle company. The company had a total of ten amphibious armored infantry combat vehicles (BMPs) and eleven antitank grenade launchers (RPG-7s). Since the Soviet force was in a defensive posture, the RPG-7s were employed independently of the BMPs.

1. Brief Description of the Scenario

The simulation consisted of a US mechanized force attacking a Soviet motorized rifle force. The Soviet forces were in prepared defensive positions, while the US forces conducted a deliberate attack on the Soviet forces.

Three different scenarios were conducted in the simulation. Initially, a US mechanized infantry battalion attacked a Soviet motorized rifle company. In the second scenario, the US forces were depleted by a total of one company's worth of weapon systems, and the equivalent strength was added to the Soviet force. In the third scenario, the US forces were depleted by an additional company's worth of weapon systems, and the equivalent strength was added to the Soviet force. A more detailed description of the tactical scenario is included in Chapter 3.

2. Operational Lethality Index

The Operational Lethality Index (OLI) is used in QJM as a measure of a weapon system effectiveness. Table 1 provides the OLIs used to calculate the force structure for each scenario in the simulation.

TABLE 1. OPERATIONAL LETHALITY INDEX SCORES[1]

Bradley Fighting Vehicle	25.9
Cavalry Fighting Vehicle	28.5
Improved Tow Vehicle	36.0
Dragon	1.6
BMP	33.4
RPG-7	0.6

The OLI scores served as input to the force strength equation. Based on the OLI scores and the number of weapon systems for both the US and Soviet forces, force strength was calculated.

3. Force Strength Calculations

The key in each of the scenarios was to insure that total force strength remained constant. This insured that a valid combat breakpoint was determined for this particular

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[1]The OLI scores used in this model were obtained in a telephone conversation with Dr. Wally Chandler of the Army's Concept Analysis Agency (CAA) in Bethesda, Maryland. The CAA is responsible for developing and maintaining all of theater level models used throughout the Army.

tactical scenario. Based on the number of weapon systems in the first scenario, a total force strength was determined. The total force strength for the first scenario based on the OLIs and the total number of weapon systems was 2425.7. For example, in the first scenario the US forces had a total force strength of 2085.1, while the Soviets had a total force strength of 340.6. Environmental factors could not be varied in the Janus model, therefore, these factors were not considered in the force strength equation.

The purpose for varying the force strength was to determine the combat breakpoint for this particular tactical scenario. Starting with a scenario that gave the US forces an almost six to one force strength ratio over the Soviet forces and ending with a scenario that had the US forces outnumbered in terms of force strength, a combat breakpoint for this particular scenario was determined. The derivation and calculation of this breakpoint is discussed in Chapter 3.

A linear program (Appendix A) was used to determine the number of weapon systems that each side would have in each scenario. The linear program maximizes the number of weapon systems based on the OLI of each weapon system. The constraint equations set lower and upper limits for each type of weapon system for each scenario. This insured that each

side maintained a proper combination of weapon systems in accordance with approved doctrine.

In all three of the simulation scenarios, the total force structure remained constant. However, the US and Soviet forces had different force structures in each scenario. For example, in the first scenario the US forces had fifty-five BFVs, six CFVs, twelve ITVs, and thirty-six Dragons. In the second scenario, the US forces had forty-two BFVs, six CFVs, nine ITVs, and twenty-seven Dragons. Based on the force strength equation, the Soviet forces increased from ten BMPs and eleven RPG-7s in the first scenario to twenty-four BMPs and twenty RPG-7s in the second scenario. This insured that the sum of the total force strength remained constant and that each side maintained an appropriate number of weapon systems. Chapter 3 discusses in greater detail the way in which weapon systems were removed from the US force, and the way in which weapon systems were added to the Soviet force.

III. SIMULATION DESCRIPTION AND RESULTS

A. INTRODUCTION

The simulation consisted of a US mechanized infantry force attacking a Soviet motorized rifle force in three different scenarios. Each scenario varied the size of the US and Soviet forces for the purpose of determining the combat breakpoint for this given scenario. The combat breakpoint is the point in which parity exists between the two forces and is the point at which the battle would theoretically end in a draw. A draw is defined as the point at which neither side has an advantage over the other side, or it is the point that each side has an equal chance of winning the battle. The output from each trial run was analyzed and a combat breakpoint was determined based on the results of the simulations. This breakpoint served as the critical component in the development of the decision aid.

The only factor varied in the simulation was the size of the force. Each scenario used the same terrain and all of the US weapon systems had the same movement routes for each scenario. Holding all of the factors, except the size of the force, constant insured that the breakpoint was a function of the force size and that other factors did not influence the

the force size and that other factors did not influence the calculated breakpoint.

B. TERRAIN

The Janus computer model has the capability of displaying and using terrain from different parts of the world. Simulated terrain representative of the US Army's National Training Center (NTC) located at Fort Irwin, California was used for the entire simulation. There were three major reasons for selecting the NTC terrain. The first reason was because of the author's familiarity with the location. This familiarity with the terrain made it easier to select a suitable location for a US mechanized force to operate. The second reason was that the terrain selected was very open with a few rolling hills, thus it did not provide the attacking or the defending force with any particular tactical advantage. This helped insure that the terrain limited any bias. However, any bias caused by the terrain was factored out by determining the operational and environmental factors in the QJM [Ref 1, page 87]. The third reason was that the area selected provided enough space for a US mechanized infantry battalion to conduct offensive operations, thus the terrain did not restrict the force's movement and enabled the US force to be deployed tactically without any restrictions.

C. TACTICAL SCENARIO

The objective of the US force was to gain and seize the key terrain occupied by the Soviet force. The US forces did not have any type of follow-on mission and would receive instructions from the next higher level of command once it seized the key terrain.

Initially, the US forces were deployed with three mechanized infantry companies abreast and one mechanized infantry company following the center company as a reserve force. The main attack occurred in the center company's sector; therefore, the center company was weighted heavier in terms of weapon systems than the other companies. The mission of the companies on the flanks was to support the main attack in the center sector, while the company following in reserve was prepared to support the main attack.

The mission and the manner in which the US forces were deployed for all three of the scenarios were the same. In order to keep the same tactical configuration, weapon systems were removed from each of the mechanized infantry companies when the size of the force was varied. For example, in the first scenario the center company had sixteen BFVs, and each of the other three companies had thirteen BFVs. In the second scenario, the center company had thirteen BFVs, while the

other companies had nine BFVs. The number of CFVs remained the same for all three scenarios, and each of the companies that were deployed on line had one of their ITVs removed between scenarios. The ITVs were not deployed with the company that was in reserve.

Initially, the Soviet force consisted of a motorized rifle company that was deployed on a key piece of terrain that controlled the movement into and out of the valley in which the operation took place. In the first scenario, the Soviet force consisted of ten BMPs and eleven RPG-7s. In the second scenario, the Soviet force was organized into two motorized rifle companies with twelve BMPs and ten RPG-7s each. In the final scenario, the Soviet forces were organized into three motorized rifle companies that consisted of twelve BMPs and eleven RPG-7s each.

D. SAMPLE SIZE CALCULATION

Once the size and type of force for each tactical scenario was specified, it was necessary to calculate the number of times that each trial should be run to determine the combat breakpoint with statistical significance. Key in determining the number of runs was establishing a level of significance. Initially, an alpha level of 0.20 was selected for the sample size calculation. This means that there is a 0.20 probability of rejecting a true test hypothesis. An alpha level of 0.20

is commonly used and accepted in the Army for test and evaluation [Ref 10]. This level was used in this model since an accepted alpha level for combat models could not be found.

The random variable measured is the number of vehicles killed in each trial run. Based on historical data from the Janus model, it was assumed that this random variable was normally distributed. Since the exact value for the standard deviation was not known, the t-distribution was used. Therefore, the sample size was calculated using the following formula:

$$n = \left[\frac{t_{1-alpha/2}\ s}{error}\right]^2$$

where,

s = Estimate of Standard Deviation

$t_{1-alpha/2}$ = the theoretical t statistic

error = error term used to calculate sample size.

In order to determine the size of the sample, it was necessary to obtain an estimate of the standard deviation and determine what would be an acceptable error term. The standard deviation used in the formula was obtained from historical data of combat simulations with similar tactical scenarios. The value of the standard deviation used was

1.333, and it was determined that an error of 0.5 would be acceptable for this simulation.[2]

Once an estimate for the standard deviation was obtained and a value for the error term established, the number of runs for each scenario could be calculated. Table 2 depicts the method used to determine the sample size using the t distribution.

TABLE 2. t DISTRIBUTION TABLE

n	$t_{0.90,n-1}$	$\left[\frac{t_{0.90}s}{\text{error}}\right]^2$
8	1.415	14.24
9	1.397	13.88
10	1.383	13.60
11	1.372	13.38
12	1.363	13.21
13	1.356	13.07
14	1.350	12.96
15	1.345	12.86
16	1.341	12.79

Column one is the value for the number of trial runs. Column two provides respective t statistics and the final column provides a calculated value of n using the sample size formula described above.

[2]This information was obtained in a conversation with Major Hirome Fujio of TRAC Monterey.

In order to obtain a value for the sample size, the value in the last column is compared with the value in the first column. The sample size is determined by selecting a value of n that had the smallest absolute value difference between the values in the first and last column. Based on these calculations, a sample size of thirteen was selected. [Ref 11]

E. ASSUMPTIONS IN THE SIMULATION

Several key assumptions were made in developing each scenario and in running each trial of the simulation. Listed below are some of the assumptions made in analyzing the results of the simulation and in developing the decision aid.

1. The computer simulation did not incorporate what Dupuy called "intangible factors" in the model, such as leadership, training, morale, and experience.
2. An alpha level of 0.20 is a valid alpha level for this combat simulation.
3. Janus is an accurate portrayal of actual combat.
4. The OLI figures obtained from the CAA are valid.

F. SIMULATION RESULTS

Each scenario was composed of thirteen different trial runs. The results for each of the runs were analyzed to determine the combat breakpoint. Table 3 depicts the 95% confidence interval for the number of weapon systems killed in each scenario.

TABLE 3. 95% CONFIDENCE INTERVAL FOR EXPECTED NUMBER OF WEAPON SYSTEMS KILLED

Scenario number	Confidence Interval
1	(29.18,30.81)
2	(72.75,76.58)
3	(43.58,45.81)

The values for the upper and lower bounds varied from scenario to scenario. Since the forces were varied on both sides between scenarios, the number of weapon systems killed was not the same for each scenario. These confidence interval figures are not used in the calculation of the breakpoint but serve as an indication of the consistency of the simulation.

1. Initial Force Ratio

The first step in analyzing the results of the simulation was to calculate the initial force ratio (IFR). This ratio is a comparison of the initial force strength of the US forces divided by the initial force strength of the Soviet forces for each scenario. The following is the formula that is used to calculate the IFR;

$$IFR = S(US)/S(Soviet)$$

where,

S(US) = force strength of the US forces

S(Soviet) = force strength of the Soviet forces.

2. Force Exchange Ratio

The force exchange ratio (FER) could not be calculated until each of the trials in each scenario was complete. This ratio compares the percentage of US weapon systems lost to the percentage of Soviet weapon systems lost. The following formula is used to calculate the FER;

$$FER = \frac{\text{Soviet weapon systems killed/ US weapon systems killed}}{S(\text{Soviet})/S(\text{US})}$$

Table 4 provides a comparison between the IFR and the FER for each scenario and was used to determine the combat breakpoint for this particular tactical situation.

TABLE 4. IFR AND FER COMPARISON

Scenario Number	IFR	FER
1	5.95	7.91
2	1.95	1.35
3	0.91	0.33

Based on the definition of the FER, if there was a one for one exchange in terms of weapon systems, the IFR would equal the FER. Therefore, based on the values listed in Table 4, the US forces killed a higher percentage of weapon systems in the first scenario; however, the Soviets killed a higher percentage of weapon systems in the second and third scenarios.

G. COMBAT BREAKPOINT CALCULATIONS

The results of the simulation were analyzed in order to determine the combat breakpoint for this particular tactical situation. Based on the data in Table 4, it was estimated that the combat breakpoint occurred when the US forces had a 1.5 IFR over the Soviet forces. This combat breakpoint is the point in which parity exists between the two forces and is the point at which the battle would theoretically end in a draw.

The value of 1.5 to 1 is a reasonable value for the combat breakpoint for this scenario. If other assets such as, close air support, fire support, mines, and engineer assets were used in the simulation the breakpoint would have been higher. This is because these assets provide the defending force a tactical advantage and serve as a combat multiplier for the defending forces.

H. RANGE OF COMBAT EFFECTIVENESS VALUES

The combat effectiveness (CE) of a force is a comparison of the degree to which the troop quality variable affects the outcome of a battle. The CE of a force is simply the ratio of the actual combat results to the theoretical combat results. The theoretical combat power of a force is a function of the force strength and the operational and

environmental factors. The theoretical combat power equation is presented below:

Theoretical Combat Power (P') $P' = S \times OE$

where,

S = force strength

OE = operational and environmental factors.

The actual battle results examines three factors:

1. the force's ability to accomplish the mission,
2. the ability to gain or hold ground, and
3. the effectiveness of a force when casualties occur.

Presented below is the actual battle results equation:

Actual Battle Results (R) $R = M + G + C$

where,

M = ability to accomplish the mission

G = ability to gain or hold ground

C = effectiveness of the force when casualties occur.

In the QJM the actual battle results is based on historical data and take into account Dupuy's Q factor which includes leadership, training, morale, and experience. Since historical data was not available for any of the scenarios used in this thesis, the equation used for the actual battle results was the combat power equation. This equation was used

since it took into account the troop quality factors that were used in developing the decision aid model.

In order for a force to have an advantage over an opposing force, the P value must be greater than one; therefore, parity between the two forces exists when the ratio of P values equals one. In this particular tactical scenario, it was determined that parity existed between the two forces when the US forces had a 1.5 IFR advantage over the Soviet forces. The simulation provided results for the theoretical combat power of the forces; therefore, based on the theoretical combat power equation, it was determined that the operational and environmental factors that affected this simulation were equal to 0.6667. This value was determined by setting the theoretical combat power equal to one and solving the equation for the operational and environmental factor. This factor took into account the fact that the US force was attacking the Soviet force. This made the theoretical combat power of the US and Soviet forces equal to one when parity existed between the two forces.

The next step was to actually calculate the range of values of the CE of the two forces. A range of values for the CE is established by using the combat power equation and substituting the CE value for the Q value in the equation. Dupuy, in his book Understanding War, made this substitution,

because he stated that the CE value takes into account the non tactical characteristics of a force [Ref 1, page 282]. The revised combat power equation used in determining the range of CE values is;

$$P(US) = S(US) \times OE(US) \times CE(US)$$

$$P(Soviets) = S(Soviets) \times OE(Soviets) \times CE(Soviets)$$

where,

P = combat power of the force

S = force strength

OE = operational and environmental factors

CE = combat effectiveness of the force.

The range of CE(US) values was determined by calculating the values needed in order for parity to exist between the US and Soviet forces. By performing these calculations, an upper and lower limit for the CE(US) was established. This range of values was calculated by setting the value of P equal to 1, the value of OE equal to 0.6667, and varying the value of S based on the IFRs used in the different scenarios. For example, in the first scenario, the IFR was equal to 5.95; therefore, the CE(US) was determined to be 0.2523 for the first scenario. Using the same procedure, the CE(US) value for the third scenario was equal to 1.656. This was based on the IFR equal to 0.907 in the third scenario. Based on the definition of the CE, the range of values for the CE(Soviets)

is the reciprocal of the CE(US). The range of the CE values calculated for both forces is well within the range of values for the CE calculated by Dupuy and his associates based on historical data [Ref 1, page 226].

This range of CE values, which established upper and lower bounds for the troop quality factors, was used in developing the decision aid model. Chapter 4 explains how the troop quality factors were broken down and applied to the decision aid model.

IV. DECISION AID MODEL DEVELOPMENT

A. INTRODUCTION

Since the days of Clausewitz and the Napoleonic Wars, the modern battlefield has grown in complexity with an increase in the number of functions a commander must perform while executing increasingly expanding command responsibilities. During Clausewitz's time a commander was responsible for about ten functions on the battlefield. [Ref 13, page 29]

The battlefield of today is much more complex. With the advent of the Airland Battle Doctrine, the commander is responsible for more than thirty different functions. For example, during the early 1800's, the maneuver forces that a commander was responsible for included only infantry and cavalry troops. Today, the maneuver forces that a commander is responsible for include infantry, armor, cavalry, and attack helicopters. In the early 1800's, the major areas of responsibility included maneuver forces, fire supports assets, engineers, intelligence, and logistical assets. In addition to each of these major areas expanding, today's commander is responsible for tactical air support, air defense artillery, and electronic warfare. [Ref 13, page 29]

In addition to the increasing complexity of the modern battlefield, the physical area of the battlefield has increased dramatically since the days of the Civil War. During the Civil War, a deployed force of 100,000 men would occupy an area of about twenty-six square kilometers. The same force covered a front of about 8.6 kilometers and extended to a depth of about 3.0 kilometers. The same commander today is doctrinally responsible for about 4,000 square kilometers. This force covers a front of about fifty-seven kilometers and extends back to a depth of about seventy kilometers. [Ref 2, page 28]

In addition to the increased responsibility of the commander and size of the battlefield, the commander now has access to enormous quantities of information for analysis and evaluation. This information, which originates from numerous sources, both on and off of the battlefield, requires evaluation and dissemination in a timely manner in order to be of maximum value. Thus, the commander must now make not only correct decisions, but they must be made with greater expedience. Delaying on the modern battlefield could mean the difference between victory and defeat.

The requirement to process tremendous amounts of information in a timely manner has led to the development and proliferation of battlefield decision aids. The decision aid

model developed here rapidly provides the commander with a predictive indication of unit performance during an engagement and thus, an indication regarding the probable outcome of the battle. This model, however, like any decision aid, is not intended to provide the definitive tactical solution nor does it make the decision for the commander. That ultimate decision, as always, rests with the commander.

The specific purpose of this decision aid model was to analyze information available to the commander and provide some type of quantitative measure that will be of assistance in selecting a course of action. This decision aid will assist the commander by enabling him to concentrate available combat power against the enemy at the proper time.

The component elements of this decision aid model included those areas evaluated by the commander in the Unit Status Report (USR). The USR is a monthly evaluation made by the unit commander that provides an overall unit rating based on four critical areas. These areas include personnel, equipment on hand, equipment readiness, and training.

The next step was to establish a relationship between the QJM and the USR. In Dupuy's QJM, he refers to certain characteristic of a unit as "intangible factors". Dupuy states that these "intangible factors" are non tactical variables that have an impact on a unit's ability to perform in combat. For

the purposes of this decision aid model, these "intangible factors" are the individual components of the USR. These components were varied in the QJM and serve as the basis for development of the model.

The decision aid model examines the commander's possible courses of action and provides a recommendation as to which course of action should be selected. Several different sources serve as input into the model and are evaluated in developing the recommended course of action. The decision aid model uses the following factors as input variables:

1. US and Soviet Initial Force Strength.
2. Operational and environmental factors such as; terrain, combat posture, and mobility.
3. Current US and Soviet doctrine concerning offensive and defensive tactics.
4. Areas evaluated in the USR.
5. Intelligence about the Soviet forces.

Each of the factors are considered by the decision aid model and a recommended course of action is developed. The algorithm used in developing a recommended course of action consists of Dupuy's revised combat power equation with the areas evaluated in the USR serving as the "intangible factors".

The commander then considers the recommended course of action and makes a decision based on endogenous and exogenous

variables that might affect the situation. The endogenous variables might include the commander's experience, intuition, training, and personal bias. The exogenous variables might include; staff officer recommendations, changes in intelligence, and restrictions placed on the force. Based on the recommended course of action from the decision aid and the variables affecting the different courses of action, the commander can now optimize the probability of taking the correct course of action.

B. UNIT STATUS REPORT

The factors evaluated by the unit commander in the Unit Status Report (USR) were used in developing the decision aid. These factors include personnel, equipment readiness, equipment on hand, and training. The USR requires commanders to evaluate their unit each month in these areas. This evaluation predicts how well a unit will perform its wartime mission based on an evaluation of the four major areas described above.

The rating scheme for the USR consists of a rating in each of the four major areas. A C1 rating is the highest possible rating that a unit can receive in each category, and a C5 rating is the lowest possible rating that a unit can receive. For the purpose of this thesis, only C1 - C3 ratings were examined. This is because C4 and C5 ratings are rarely given,

and a C5 rating can only be given to a unit with Department of the Army approval.

1. <u>Personnel</u>

The personnel evaluation is calculated by comparing the available strength, available military occupational skill (MOS) trained strength, and the available senior grade strength. An MOS is the soldier's area of technical expertise. <u>Army Regulation 220-1</u> states that an overall personnel rating is assigned to a unit based on the lowest rating assigned to any one of the three areas described above [Ref 14; page 15].

The available personnel strength is determined by comparing the number of personnel that a unit is capable of deploying against the number of personnel that a unit is required to have based on the unit's table of organization and equipment (TOE). This strength is calculated by using the following formula;

$$\text{Available personnel strength} = \frac{\text{assigned strength}}{\text{required strength}}\ .$$

Table 5 describes how the rating is determined for the available personnel strength.

TABLE 5. RATING FOR AVAILABLE PERSONNEL STRENGTH

C rating	Criteria (% Available personnel strength)
1	> 90
2	80 - 89
3	70 - 79

The available MOS trained strength is a comparison of the number of available MOS trained personnel with the number of required MOS trained personnel. The comparison includes both officers and enlisted personnel. An MOS trained officer must have completed the officer basic course and receive his commander's recommendation regarding combat skills. An enlisted person is considered MOS trained if serving in either his primary or secondary MOS. These combat skills are individual skills and are not a measure of how well an officer or enlisted person will perform in the unit collectively. The following formula is used to determine the available MOS trained personnel;

$$\text{Available trained MOS personnel} = \frac{\text{Avail. MOS trained strength}}{\text{Required strength}}.$$

The available senior grade compares the number of officers and non commissioned officers that a unit has with the number of officers and non commissioned officers that a unit is required to have according to the unit's TOE. The

formula listed below is used to compute the available senior grade;

$$\text{Available Senior Grade} = \frac{\text{Available Senior Grade}}{\text{Required Senior Grade.}}$$

Table 6 is used to determine the rating for the available trained MOS personnel and the available senior grade.

TABLE 6. RATING FOR AVAILABLE MOS TRAINED PERSONNEL AND AVAILABLE SENIOR GRADE PERSONNEL

C rating	Criteria (% Available Senior Grade & MOS Trained)
1	> 85
2	75 - 84
3	65 - 54

Based on the evaluation of each of the personnel areas, an overall rating is assigned to the personnel category. This rating is determined by the lowest rating in any one of the personnel areas examined.

2. Equipment on Hand

An overall rating is given to unit by comparing the amount of equipment that a unit has on hand with the amount of equipment that a unit is required to have on hand in order to perform its wartime mission. Each item that is identified in the unit's TOE as critical is evaluated and assigned a numeric value based on the percentage of equipment that the

unit has on hand. Table 7 describes how the numeric values are assigned to each item in the TOE.

TABLE 7. EQUIPMENT ON HAND EVALUATION

Numeric value	Criteria (% of equipment on hand)
1	> 90
2	80 - 90
3	65 - 80
4	< 65

Based on this evaluation, the following calculations are made where,

A = (equipment with numeric value of 1) x 1

B = (equipment with numeric value of 2) x 2

C = (equipment with numeric value of 3) x 3

D = (equipment with numeric value of 4) x 4

E = (A + B + C + D)/ total amount of equipment evaluated.

E is then used to determine the equipment on hand rating. Table 8 lists the criteria for the equipment on hand rating.

TABLE 8 EQUIPMENT ON HAND C RATING

C rating	Criteria (final value calculated)
1	< 1.30
2	1.31 - 2.20
3	2.21 - 3.10

3. Equipment Readiness

This rating is determined by computing the total number of days that a unit's equipment is capable of performing its mission and dividing this number by the total number of equipment days in the evaluation period. Table 9 lists the rating criteria for equipment readiness.

TABLE 9. EQUIPMENT READINESS RATING

C rating	Criteria (% mission capable)
1	> 90
2	70 - 89
3	60 - 69

4. Training

The last area involves an overall evaluation of the unit's training status. The evaluation is based on the unit's ability to perform its wartime mission. The standard used is the Mission Essential Task List (METL) that describes the unit's wartime mission. The METL is developed by the unit commander and is submitted to the next higher level of command for approval. The training rating is based on the commander's estimation of the number of days that the unit will require in order to be trained to the standards described in the METL. These training standards are a measure of unit's training

status as a whole. Table 10 describes the criteria used to assign a rating to training.

TABLE 10. TRAINING RATING

C rating	Criteria (number of days required to train to METL Standards)
1	0 - 14
2	15 - 28
3	29 - 42

5. Overall Unit Rating

The unit is assigned an overall rating based on the ratings of the four areas described above. Each area is considered to have the same amount of weight in determining the overall rating. The unit's overall rating is equal to the lowest rating given to one of the four areas. For example, if a unit has a C2 rating in personnel and equipment on hand, a C3 rating in equipment readiness, and a C1 rating in training, the unit is assigned an overall rating of C3. For the purpose of developing a decision aid model, an overall rating was not assigned to the unit. Each of the four areas are considered independently in the model, because results from one of the four areas evaluated did not serve as input to any of the other areas evaluated.

C. DECISION AID MODEL DEVELOPMENT

In developing the decision aid model, all of the factors evaluated in the USR were weighted equally as consistent with Army Regulation 220-1. This, fortunately, made it easier to develop a decision aid model that took Dupuy's Q factor into account, because it reduced the number of total combinations in the model.

It was necessary to develop a baseline for the decision aid model. It was determined that the baseline case would occur at the combat breakpoint or when the US forces had a 1.5 IFR over the Soviet forces. This baseline case occurred when the US forces had a C2 rating in personnel, equipment on hand, equipment readiness, and training. This baseline was established because, it is extremely rare that a unit receives a C1 rating in all of the areas evaluated. Also, a C2 unit is typical of the average unit. This baseline case serves as a means to compare all of the different possible cases.

The next step in developing the decision aid model was to examine the extreme cases. One extreme occurs when a unit is rated a C1 in all areas, and the other extreme occurs when the unit is rated a C3 in all areas. For the case when a unit is rated a C1 in all areas, it was determined that the US forces needed only a 0.91 IFR over the Soviet forces in order to achieve parity. However, in the case where the unit is rated

a C3 in all of all areas, it was determined that the US forces needed a 5.95 IFR over the Soviet forces in order to achieve parity.

Since each factor is equally weighted and the IFRs for the two extreme cases were established, the value for each of the four areas could be determined. This value for each area was determined using the revised combat power equation described in Chapter 3. Key in calculating these values was the assumption that the four areas are independent of each other. This meant that the rating that a unit received in personnel had no impact on the rating that a unit received in equipment on hand. Recall from Chapter 3, the revised combat power equation is;

$$P = S \times OE \times CE$$

where,

P = combat power of the force

S = force strength

OE = operational and environmental factors

CE = combat effectiveness of the force.

For the purposes of the decision aid model, the CE value in the revised combat power equation is composed of four different variables. These four variables are personnel, equipment on hand, equipment readiness, and training. The OE value was described in Chapter 3 and was determined to be

equal to 0.6667. If a unit is to achieve parity in combat the P value in the revised combat power equation must equal one; therefore, based on the revised combat power equation with P equal one and OE equal 0.6667, a value for each one of the four areas evaluated in the USR could be determined. Using the revised combat power equation, Table 11 lists the values for each rating that would be used in the revised combat power equation.

TABLE 11. REVISED COMBAT POWER EQUATION VALUES

C rating	Value used in revised combat power equation
1	1.134
2	1.000
3	0.709

These values were used in the revised combat power equation to determine what the IFR for the US forces must equal in order for the US forces to achieve parity with the Soviet forces on the battlefield. For example, if the US forces had a C1 rating in training, personnel and equipment on hand and a C3 rating in equipment readiness, the US forces would need a 1.45 IFR over the Soviet forces in order to achieve parity on the battlefield. Critical in the calculation of these values is that the US forces were attacking a defending Soviet force.

Since each of the factors are equally weighted, order did not have an impact on the IFR determined in the revised combat power equation. For example, if a unit had a C2 rating in training, personnel, and equipment readiness and a C1 rating in equipment on hand, it would need the same IFR to achieve parity as a unit that had a C2 rating in equipment on hand, equipment readiness, and personnel and a C1 rating in training. A computer program (Appendix B) was written to determine the IFR that the US forces must have in order to achieve parity with the Soviet forces on the battlefield. The program uses the rating of each of the four areas evaluated in the USR to determine the IFR needed to achieve parity. Table 12 lists the IFR needed to achieve parity based on all possible rating combinations.

TABLE 12. IFR AND C RATING COMPARISON

C ratings	IFR
1 1 1 1	0.91
1 1 1 2	1.03
1 1 2 2	1.17
1 2 2 2	1.32
1 1 1 3	1.45
2 2 2 2	1.50
1 1 2 3	1.65
1 2 2 3	1.87
2 2 2 3	2.12
1 1 3 3	2.33
1 2 3 3	2.64
2 2 3 3	2.99
1 3 3 3	3.72
2 3 3 3	4.22
3 3 3 3	5.95

Listed below are two examples that illustrate the use of Table 12.

1. Example 1

A mechanized infantry battalion is preparing their monthly USR. The battalion executive officer has the overall responsibility of consolidating all of the information and preparing the report. He receives the following information from his staff officers. In the area of personnel, it is reported to him that the unit has 93% of the assigned personnel strength, 87% of the available MOS trained personnel, and 83% of the available senior grade personnel. Equipment on hand is reported to have a value of 2.57. Equipment readiness is reported to be 87% for the rating period, and the commander feels that the unit needs 17 days to train in order to be able to perform all of their METL tasks to standards.

Based on this information, the battalion executive officer determines that the unit will receive a C2 rating in the personnel area, a C3 rating in the equipment on hand area, a C2 rating in the equipment readiness area, and a C2 rating in the training area. Using Table 12 and the evaluated status in the USR, this unit will need a 2.12 IFR over the Soviets in order to achieve parity on the battlefield.

2. Example 2

The following month this same unit received some new equipment to replace some of the older equipment on hand and to replace some of the existing shortages. Based on this information, the unit improved its rating in the equipment readiness area from a C2 to a C1 and improved its rating in the equipment on hand area from a C3 to a C1. Personnel and training both remained C2 for the rating period. Based on this information and the values listed in Table 12, the unit will need a 1.17 IFR over the Soviets in order to achieve parity on the battlefield.

D. SUMMARY

In developing the decision aid model, there are several critical assumptions made in the model development. These assumptions include:

1. Independence of each of the factors evaluated in the USR.
2. C2 rated unit served as the baseline unit.
3. Each of the factors is considered separately and an overall unit rating is not assigned.

The validity of these assumptions is not the critical component of the model. The key is the methodology used in developing the model. Different assumptions can be made and

used to develop different results; however, the concepts and equations developed in this model can be tailored to adapt to any type of tactical situation and assumptions.

V. CONCLUSIONS AND RECOMMENDED RESEARCH

A. INTRODUCTION

Since the days of the ancient Chinese warriors, attempts have been made to determine what type of tactical situation must exist in order for a commander to attack a defending force. Sun Tzu stated that if the following conditions exist, the force commander should conduct the following type of operations:

1. If you outnumber the enemy ten to one, your objective is to surround the enemy.

2. When you outnumber the enemy five to one, you attack the enemy.

3. If the attacking force has double the strength of the enemy, the objective is to divide the enemy.

4. If the forces are equal, you may engage the enemy. [Ref 15, page 79-80]

Sun Tzu's strategy only addressed the numerical advantage that one force had over another force. His strategy did not consider other factors that could influence the outcome of the battle. These factors include variables such as quality of leadership, state of training, morale, and the experience of the force.

The objective of this thesis is to develop a decision aid model that considers factors other than just the strength of

a force compared to the strength of another force. The factors examined included the effects of terrain, combat posture, and mobility of a force, and the effects that non tactical variables have on a battle.

B. CONCLUSIONS

The decision aid model uses the theoretical combat power equation formulated by Dupuy and his associates. The model examines factors such as force strength, intelligence, terrain, environmental factors, and "intangible factors" in developing a recommended course of action.

Dupuy's QJM is the critical component of the decision aid model. Chapter Two explained how the QJM was developed and how this model relies on historical data instead of projections of future weapon systems. The validity of the QJM has, in the past, been verified by comparing the results achieved with the QJM with the results of actual battles.

The next phase consisted of a computer simulation, with results from this simulation being used in the development of a combat breakpoint. This breakpoint is a key factor in the development of the decision aid model.

The final phase is the actual development of the decision aid model. The decision aid model consists of the results of the simulation and what effects the factors such as personnel, equipment on hand, equipment readiness, and training would

have on the results. The model thus provides the commander with a recommended course of action.

The simulation used only one type of tactical situation, and several assumptions were made in the development of the model. The validity of the assumptions and the type of tactical situation are not the primary focus. The primary focus is the methodology used in developing the equations and model used in determining a recommended course of action. The tactical situation can change and different assumptions will produce different results. However, the methods used to obtain the results remain the same. The framework and foundations have been laid for further development of this model as applicable to any type of tactical situation.

The model developed here provides the commander with a recommended course of action. As mentioned earlier, the commander can accept or reject the recommended course of action based on other factors that might affect his decision. The "intangible factors" used in the model consists of a system that the Army currently uses and did not require that a new evaluation system be developed in order to serve as input for the model.

The importance of using historical data to develop a model cannot be overemphasized. As Dupuy mentioned, "military history is the laboratory for the soldier" [Ref 1, page xxii].

The importance of history on the battlefield can be summed up by a quote made by General George S. Patton in a letter to his son that states: "To be a successful soldier you must know history. What you must know is how man reacts. Weapons change but man who uses them changes not at all. To win battles you do not beat weapons - you beat the soul of man of the enemy man." [Ref 16, page 791] The QJM is a model that considers the historical aspect; therefore, this was a major reason for its selection as the model that was incorporated into the decision aid.

C. RECOMMENDED RESEARCH

This thesis covered only a small portion in the area of decision aid models. Several other aspects of the model could be examined to improve or expand the model. The following recommendations are offered:

1. Use the same model but incorporate other factors into the model such as indirect fire support, mines, engineer assets, chemical warfare, and task organizing the force.

2. Develop other human factor issues that could be used in the model. Examples include some of the seventy-three "intangible factors" that Dupuy and his associates developed.

3. Examine whether each of the factors in the USR should be weighted equally. Determine the relative weights of each of the factors in the USR. Also, examine whether or not these factors are independent and can be treated as independent.

4. Validate the decision aid model against actual historical data.

APPENDIX A LINEAR PROGRAM

Index: i = OLI index of summation

Given Data: OLIs

1 = 25.9

2 = 28.5

3 = 36.0

4 = 1.6

5 = 33.4

6 = 0.6

Decision variable

n_i = number and type of weapon system used in each scenario

Formulation

Maximize $\Sigma_{i=1,6}$ OLI_i n_i

subject to:

OLI_i n_i $\geq$ Lower $Bound_i$

OLI_i n_i $\leq$ Upper $Bound_i$

$\Sigma_{i=1,6}$ OLI_i $n_i \leq$ 2425.7

$n_i \geq 0$

Note: For each scenario the lower and upper bounds for each weapon system changed.

APPENDIX B COMPUTER PROGRAM

This program was written in Turbo Basic and was used to calculate the initial force ratio needed for a unit to achieve parity on the battlefield. The input variables were the C ratings for a unit in the four major areas evaluated in the Unit Status Report.

Main Program

```
GOSUB InputData
GOSUB Initialize
START:
GOSUB Train
GOSUB Equip
GOSUB OnHand
GOSUB Pers
  CLS
GOSUB OutputData
END
```

Subroutines

```
Initialize:
If OutputFile$ = " " then OutputFile$ = "con"
Open OutputFile$ for Output AS 1
Return


InputData:
CLS
Input "Output File =                ";OutputFile$
Return

Train:
CLS
Input  "Enter your C value for training ";Train
If Train = 1 then
```

```
  T = 1.134
ElseIf Train = 2 then
  T = 1.0
Else
  T = 0.7087
End If
Return
Equip:
Input  "Enter your C value for equipment readiness";Ready
If Ready = 1 then
  E = 1.134
ElseIf Ready = 2 then
  E = 1.0
Else
  E = 0.7087
End If
Return


OnHand:
Input  "Enter your C value for equipment on hand";OnHand
If OnHand = 1 then
  H = 1.134
ElseIf OnHand = 2 then
  H = 1.0
Else
  H = 0.7087
End If
Return


Pers:
Input  "Enter your C value for personnel";Pers
If Pers = 1 then
  P = 1.134
ElseIf Pers = 2 then
  P = 1.0
Else
  P = 0.7087
End If
Return

OutputData:
A = P * T * E * H
R = 1/A
G = R/0.6667
Print#1, "C rating of ";Train;"in training"
Print#1, "C rating of ";Ready;"in equipment readiness"
Print#1, "C rating of ";OnHand;"in equipment on hand"
```

```
Print#1, "C rating of ";Pers;"in personnel"

Print#1, "You will need a ";G; " to 1 initial force ratio in
order to achieve parity on the Battlefield."
INPUT "Type 1 if you wish to continue or 2 to end";Mission
  If Mission = 1 then GOTO START Else
Return
```

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Thesis
M854 Moughon
c.1 A decision aid model for a maneuver force commander that incorporates the Quantified Judgment Model.